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Loss of agro-productive soils resulting from urban sprawl in Ambato-Ecuador Pérdida de suelos agroproductivos por el crecimiento de la mancha urbana en el cantón Ambato

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ABSTRACT With the passage of time, humanity has transformed a sea of rurality with some urban islands into a metropolitan sea with areas of countryside and nature (Naredo, 2004). Day after day, cities waterproof large areas of land, many of them with agricultural potential that have been lost under asphalt and cement. In recent years, small and medium-sized cities have gained territorial relevance by becoming urban centers of regional importance, not only because of their political, administrative, functional, socioeconomic, and physical scope, but also because of the possibility of avoiding repeating the mistakes of the large metropolises by maintaining harmony in rural-urban relations. In this context, this research analyzes how the horizontal urban growth has buried the best agricultural soils in its path, through the case study of the city of Ambato.

RESUMEN Con el paso del tiempo, la humanidad ha ido transformado un mar de ruralidad con algunas islas urbanas en un mar metropolitano con zonas de campo y naturaleza (Naredo, 2004). Dia tras día las ciudades impermeabilizan amplias superficies de suelo, muchas de ellas con aptitudes agrícolas que se han perdido bajo el asfalto y cemento. En los últimos años las pequeñas y medianas ciudades han obtenido relevancia territorial al convertirse en centros urbanos de importancia regional, no solo por el ámbito político administrativo, funcional, socioeconómico y físico, sino también, por la posibilidad de evitar repetir los errores de las grandes metrópolis manteniendo armonía en las relaciones campo-ciudad. En este contexto, la presente investigación analiza como el crecimiento urbano horizontal ha sepultado a su paso a los mejores suelos agroproductivos, mediante el estudio de caso de la ciudad de Ambato.

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1. Introduction
1.1. Contextualization of the case study

Ambato is an Andean region located in the centre of the country, at an average altitude of 2,620 meters above sea level, and it is the capital of the Tungurahua province. Its territorial jurisdiction is characterized by numerous geological faults in the northern and eastern areas of the city, which have contributed to the occurrence of major earthquakes.

"Ambato", according to its Quechua roots, means "place of the black toads", referring to the ancient presence of certain species of amphibians with these characteristics that were abundant in its ravines. However, over time, this description has changed drastically, transforming its conception into that of a locality known as a great "market city" (Vera, 2000).

In this context, to determine the origin of Ambato's conception as a market city, it is important to go back in time to its very foundation. In 1535, Sebastián de Benalcázar established the town of Ambato, located on the right bank of the river of the same name. From that point, a series of events occurred that shaped the vocation of the canton until today.

In 1570, Antonio Clavijo, president of the Royal Audience of Quito, founded San Juan Bautista de Ambato and laid out the streets, plazas, and the site where the main church should be built, maintaining the traditional Spanish structure where the Plaza Mayor was the central nucleus, around which the main church, the municipal building, and the barracks were constructed (Criollo Zurita and Villacrés Arias, 2018).

In 1689, the city was affected by a violent earthquake that completely destroyed it, and it had to be relocated and reestablished on a terrace of a bend in the Ambato River. Initially, the region where the city is situated was uninhabited, but the Spanish chose this location with strategic military considerations to defend against native attacks and for territorial dominance (Vera, 2000).

At that time, the areas now known as Píllaro, Patate, Pelileo, and Cunchibamba surrounded Ambato and were the true centres of product exchange and trade. These areas had indigenous road systems, which over time facilitated Spanish domination, transforming Ambato and its surroundings into an agricultural and artisanal centre during the colonial period. It became a hub for the production of textiles, shoemaking, cabinetmaking, and leather tanning (Vera, 2000).

Centuries later, the arrival of the railroad in 1906 became the catalyst for the economic boom of the central region of the country, including Ambato, which transformed into a centre of convergence, collection, and agricultural production that was later distributed to the Coast, Highlands, and Amazon regions of Ecuador (GADM Ambato, 2021).

With Ambato establishing itself as an intermediate city, it became a socioeconomic enclave for agricultural and commercial activities, with a direct influence on the development of the actors involved. Since much of Ambato's territory is a producer of vegetables, legumes, flowers, and fruits, it has become an ideal area for agriculture and livestock farming, which have been developed intensively to this day, driven by the demand for food and the concept of food security in other regions of Ecuador (GADM Ambato, 2021).

The canton of Ambato is characterized by its strong commercial and manufacturing orientation, with wholesale and retail trade of products from agro-industries, artisanal, and industrial sectors occurring daily.

This, combined with the city's strategic location—situated along the route to the coastal region and as the gateway to the Amazon—with its characteristic microclimates that aid in the cultivation of various agricultural products, has made Ambato an attractive destination. The city's dynamic market has transformed it into a compelling option for internal migration, as people seek better opportunities and spaces for economic development.

In its local planning through the Land Use and Management Plan 2033 (GADM Ambato, 2021), the canton aspires to become a productive and commercial hypocentre for the central region of the country, capable of stimulating agricultural, artisanal, manufacturing, and agro-industrial production.

However, this set of social, economic, and spatial characteristics has generated various impacts and challenges, including:

- The process of economic and demographic growth has led to gradual land occupation, often in a disorganized and spontaneous manner, where the population itself has created its own mechanisms for growth and expansion. The city's outskirts have grown through subdivisions that lack predetermined organization or design, often emerging as informal neighbourhoods, sometimes even extending beyond established urban boundaries (GADM Ambato, 2021).

- The city has also expanded onto agricultural lands, displacing productive activities to the outskirts and neighbouring cantons, thereby losing its agricultural vocation as this land becomes urbanized for commercial and residential use.

1.2. Theoretical foundation

1.2.1. Globalization and sustainable cities

Since the formation of the first cities, there has been a clear distinction between the boundaries of the countryside and the city due to their differences in functions, landscapes, morphology, social classes, lifestyles, interests, and tastes. However, today, the urban-rural transition space is positioned as an expanding area where both urban and rural elements and functions are mixed. This environment is undergoing changes in land use, economic activities, and the behaviour of its residents (Cardoso and Fritschy, 2020).

Throughout history, the growth of cities has been based on the opportunities provided by the location of these urban centres. As generations evolve, human needs increase, and public services must be improved to meet the growing demands of urban settlements. The construction of public infrastructure drives the transformation of housing and improves the quality of life in these communities (Villa and Cabay, 2017).

In recent decades, the accelerated urbanization of large and medium-sized cities has led to increasingly significant environmental problems worldwide. The trend in urban ecosystems is to concentrate more population and economic activities in a spatially limited area, with a notable impact on the environment and quality of life (Henríquez, 2014).

Both in developed and developing countries, trends in the spatial growth of urbanized areas have emerged, requiring more resources and energy from the environment for the functioning of towns and cities. Furthermore, evidence suggests that medium-sized cities will be the most important in this dynamic, as these cities typically have less environmental documentation for their management (Henríquez, 2014).

Globalization has instilled in the minds of people worldwide the desire to live in large cities filled with lights, restaurants, and all types of commerce. However, beneath the glow of modernity, these cities conceal unsustainability and a dependence on food, water, and natural resources from surrounding areas to meet their needs.

1.2.2. Environmental impacts of urbanization

Urbanization has driven the development of civilization and has become increasingly crucial for human progress. However, the growing and accelerated urbanization processes have harmful consequences, particularly in the loss of natural resources and environmental pollution (Salazar, 2020).

When a human action or activity causes an alteration (positive or negative) in the environment or any of its components, it simultaneously generates an environmental impact (Vera, 2015).

The city, in addition to representing a cultural, geographical, social, and economic space, also has an ecological dimension. The city is an open system with boundaries related to the flow of energy and matter. However, the boundaries of the city are much broader and more complex than just the divide between built and unbuilt areas, as are the environmental impacts it causes. These impacts are primarily evidenced in land use or land cover changes and can reach local, regional, and even global scales (Henríquez, 2014).

The environmental, social, and economic consequences of rapid land expansion include habitat loss, species extinction, pressure on resources and natural space, degradation of ecosystem services, and the loss of fertile, high-productivity agricultural land (Bernal et al., 2022).

1.2.3. Impacts of urbanization on agricultural soils

Urban soils provide significant environmental services, such as retaining and supplying nutrients, serving as a growth medium and substrate for soil fauna and flora, and absorbing and storing water (Pickett et al., 2001, as cited in Henríquez, 2014). However, urban soils have been modified by human activities, leading to functional alterations.

Natural soil has been covered by "urban cover", such as asphalt and concrete, which introduces both direct and indirect factors that affect the natural functioning of the soil (Henríquez, 2014).

Direct effects on the soil include physical disturbances such as burial, filling with materials, and surface impermeabilization. Indirect effects involve changes in the biotic and abiotic environment, which in turn influence soil development (Pickett et al., 2001, as cited in Henríquez, 2014).

Among the effects, notable ones include: the creation of heat islands, loss of vegetation cover impacting air quality, increased surface runoff, and the loss of potentially agricultural soils, which diminishes the capacity to produce food, among others.

Indiscriminate urban expansion frequently impacts agricultural lands, and despite this significant loss, there is still no complete scientific understanding of future global patterns of urban sprawl. It is estimated that by 2030, indiscriminate urban expansion will result in a loss of 1,8 to 2,4% of global agricultural lands, which are responsible for 3 to 4% of global food production (Casas et al., 2020).

Finally, it should be emphasized that the phenomenon of urbanization acquires global dimensions and, depending on the context, presents very different intensities and characteristics. According to Bellet Sanfeliu (2009), almost all urban growth will be concentrated in less developed countries, where, in recent years, large cities have grown more slowly compared to medium and smaller cities.

As a result, these cities are beginning to gain more importance in the settlement system in Latin America due to the new population and economic dynamics they are experiencing. Intermediate cities have become centres of services and facilities that cater not only to the inhabitants of the city itself but also to those residing in its surrounding area.

1.2.4. Urbanization of rural land in Latin America

In Latin America, the transformation of rural areas into urban ones is among the effects of globalization processes, which have primarily led to accelerated urbanization with high demand for land for housing and the loss of agricultural land, creating *"rurbanos"* spaces that represent areas of increasing expansion and overlapping elements and functions (Cardoso and Fritschy, 2012).

Salazar and Paliz (2018) state that the peripheral areas resulting from city growth have undergone intense processes of change due to various pressures, including population growth and land use and construction demands stemming from urban expansion.

In the American continent, the urbanization of rural land has become a frequent issue. To illustrate this, three cases of cities facing this process are characterized, located in Chile, Bolivia, and Argentina.

- Santiago, Chile

Armijo (2000) identifies that in the Metropolitan Region of Santiago, the field-city relationships are situated in a context characterized by technological acceleration, financial concentration, and the immediate dissemination of information. Consequently, the productive specialization of the Chilean countryside has caused serious impacts on the settlement patterns of the rural population. The process of peri urbanization has led to the loss of highly productive agricultural land on the periphery of Santiago, resulting in the deterioration of the rural environment and specifically of the agricultural activities carried out there.

Armijo (2000) also mentions that, according to a 1991 study by CIREN-CORFO, the urban area of Greater Santiago has quadrupled in 50 years, resulting in the loss of agricultural land on the periphery, exceeding the area that the Chilean capital occupied from its founding until 1940. Of this lost land, over 90% corresponds to highly productive agricultural soils suitable for all types of horticultural and fruit crops.

Finally, the study identifies that the rapid urbanization process experienced in the Metropolitan Region's countryside has led to the creation of conflicting spaces, where the rural habitat has been gradually disappearing (Armijo, 2000).

- Cochabamba, Bolivia

The second case is based on the study by De la Fuente and Cabrera (2016), which analyses the city of Cochabamba, once considered a highly productive territory and even referred to as the "granary of Bolivia." However, over the years, the conditions of the valley where the city is located have changed drastically. Cochabamba has ceased to be Bolivia's granary due to significant demographic growth, rapid expansion, and the continued conversion of agricultural land for residential activities.

In the Latin American context, determining the boundary between urban and rural land is highly complex, as urban growth processes often do not follow traditional urban planning regulations that set limits for urbanization. Consequently, land occupation processes have been predominantly informal, driven by the illegal market, demographic pressure, and other factors (De la Fuente and Cabrera, 2016).

De la Fuente and Cabrera (2016) also state that the urban growth experienced between 1988 and 2016 in the central valley of Cochabamba has resulted in a loss of around 10,000 hectares of agricultural land. This significant decrease is threatening the ability to produce food not only for Cochabamba but for the entire country.

This excessive growth of urbanized areas could be attributed to strong pressure from a free and unregulated real estate market, as well as to a weak public sector in fulfilling its responsibilities. The public sector has directly promoted the expansion process by failing to ensure compliance with its responsibilities regarding sustainable urban development and allowing private interests to overshadow collective interests.

- Buenos Aires and Rosario, Argentina

A third example of rural land urbanization can be identified in the cities of Buenos Aires and Rosario. According to Morello et al. (2000), urban expansion not only encroaches upon the most productive agricultural lands but also significantly contributes to the destruction of biodiversity.

The authors note that since the 1940s, there has been intense conversion of high-quality agricultural land in the rolling Pampas into urban, residential, and industrial areas. This transformation has had more complex effects on the rural environment and has extended beyond what was necessary for buildings, roads, and facilities.

At the time of the study, the authors state that 60% of the demand for residential land was directed towards the peripheries, primarily generated by the upper-middle class.

As evidenced in the previous paragraphs, the loss of rural land due to urbanization occurs throughout Latin America and affects both the surrounding regions of capital cities and intermediate cities.

1.3. Research problem

Based on the background provided, the focus of this research is to analyse the impact of accelerated urban growth on the territory of an intermediate city with a historical agricultural vocation and presence of high-quality soils for cultivation. The research question is: How does the horizontal expansion of the city affect the reduction of available agroproductive land in the canton of Ambato?

In response, this study hypothesizes that uncontrolled urban growth in the canton of Ambato has encroached upon predominantly agricultural land, resulting in an irreversible loss in both the quantity and quality of land available for cultivation.

For the proper analysis of the problem and hypothesis, the research objective is established as: determining the extent of anthropogenic encroachment on the territory and the transformation of agricultural land into urbanized land. To achieve this, the specific objectives are:

i) Quantify the anthropogenic areas from 1990 to 2018. ii) Compare anthropogenic expansion with the urban delimitations established in various administrative and regulatory acts developed by the municipality. iii) Identify and quantify the agricultural soils in the canton. iv) Establish a multi-temporal comparison of anthropogenic occupation of agroproductive soils.

2. Methods

The amount of agricultural land lost due to urban expansion is a significant indicator of urban sustainability due to the irreversibility of the process, as it is very difficult for urban land to revert to agricultural or natural use (Henríquez, 2014). Therefore, this study analyses the growth of the urban footprint on both the quantity of agricultural land and the quality of the agricultural soil consumed by developing a multi-temporal analysis.

The methodology employed involves a quantitative overlay of layers in GIS. Firstly, it accounts for the growth of the urban footprint by quantifying anthropogenic areas defined by the Ministry of Environment, Water, and Ecological Transition (Ministerio del Ambiente Agua y Transición Ecológica, 2016), as shown in the table below:

From Table 1, the classification of Level I, corresponding to anthropogenic areas with populated zones and infrastructure, is used as indicators of areas impacted by human activities for urban land use for the years 1990, 2000, 2008, and 2018.

Secondly, the quantity of available agricultural soils over the territory is quantified based on the agrological classification by CLIRSEN, SENPLADES, and SISAGRO (2011).

This classification categorizes land according to the degree of limitations due to factors such as erosion, soil, moisture, and climate, into eight classes as detailed below:

- Class I: Land with very slight limitations
- Class II: Land with some limitations
- Class III: Land with severe limitations
- Class IV: Land with very severe limitations
- Class V: Land for pastures or forests
- Class VI: Land with slight limitations for pastures and forests
- Class VII: Land with severe limitations for pastures and forests
- Class VIII**:** Land with very severe limitations for any use.

It is important to clarify that this classification implemented in Ecuador is based on international methodologies such as the PRAT methodology, DINAREN, the T.C. SHENG system, and the American USDA-LCC system (CLIRSEN, SENPLADES, and SISAGRO, 2011).

Therefore, for this study, the first four agrological classes (I to IV) are considered, as they are reserved for agricultural uses, while the remaining four classes (V to VIII) correspond to non-agricultural uses such as pastures, forests, protected areas, etc., which are not the focus of this research.

Thirdly, based on the study by Henríquez (2014), agricultural soils are subclassified according to their quality into: Very good, good, fair, poor, and very poor to similarly quantify them (Table 2).

Level I	Level II	Operational Definition
Forest	Native Forest	Tree ecosystem, primary or secondary, regenerated by natural succession.
	Forest Plantation	Anthropogenically established tree mass with one or more forest species.
Shrub and Herbaceous Vegetation	Shrub vegetation	Areas with a substantial component of native non-tree woody species.
	Wasteland	Tropical high Andean vegetation characterised by dominant non-tree species including fragments of native forest typical of the area.
	Herbaceous Vegetation	Areas consisting of native herbaceous species with spontaneous growth, which do not receive special care.
Agricultural Land	Annual Cropping	Includes land devoted to agricultural crops with a seasonal growing cycle.
	Semi-permanent cultivation	This includes land devoted to agricultural crops with a growing season of between one and three years.
	Permanent Cultivation	This includes land devoted to agricultural crops with a growing season of more than three years.
Agricultural Land	Grassland	Herbaceous vegetation used for livestock purposes, which requires cultivation and management for its establishment.
	Agricultural Mosaic	They are groupings of cultivated species that are mixed together and cannot be identified individually.
Water Body	Natural	Superficie y volumen asociado de agua estática o en movimiento.
	Artificial	Superficie y volumen asociado de agua estática o en movimiento asociadas con las actividades antrópicas y el manejo del recurso hídrico.
Anthropic Zone	Populated Area	Areas mainly occupied by dwellings and buildings used for public services or collectivities.
	Infrastructure	Transport, communication, agro-industrial and social civil works.
Other Lands	Area without vegetation cover	Areas devoid of vegetation, which due to their edaphic, climatic, topographic or anthropic limitations, are not exploited for agricultural or forestry use.
	Glacier	Snow and ice located on the summits of Andean elevations.
No Information		Corresponds to areas that could not be mapped.

Table 1: Land cover and land use. Ministry of Environment Water and Ecological Transition, (2016)

After collecting the necessary information in shapefile format, the layers of anthropogenic areas for the four years of analysis are intersected with the surfaces of agricultural soils and then with the surfaces of these soils, separated by quality. This allows for the yearly determination of the loss in quantity and quality of soils, to assess the impact that the expansion of anthropogenic areas is having on the productive territory of Ambato.

3. Results

3.1. Historical analysis of cantonal urban boundaries

Based on the determination of historical contexts from publications such as GADM Ambato (2021); Vera (2000); and Criollo Zurita and Villacrés Arias (2018), a timeline of historical events influencing the urban growth of the city of Ambato is established. This timeline begins with a key milestone—the arrival of the train in 1906—and extends to the most recent update of urban boundaries in 2012.

Starting in 1906, the city of Ambato began to expand following a grid-like urban layout, a legacy of Spanish colonial urban planning. This characteristic pattern of colonial cities consisted of a grid of streets and blocks, which shaped the initial growth of the city.

In 1949, a powerful earthquake devastated the city, causing severe physical damage and numerous casualties. This disaster necessitated the reorganization of the city and the implementation of its First Regulatory Plan. This plan included the planning of new neighbourhoods, and the construction of public works aimed at modernizing the city and mitigating risks in future disasters.

In 1956, with the availability of aerial photography, the expansions of the urban territory could be identified with greater accuracy. It was noted that the city's growth was starting to orient towards the peripheries, mainly southward from the central area. By that time, the estimated urban area of Ambato was approximately 3,33 km^2. This expansion reflected a trend toward more dispersed urbanization, with a clear preference for areas close to but away from the central core, a dynamic that would gradually affect the surrounding agricultural lands.

In 1963 and later in 1966, the urban growth of Ambato showed new connections with the peripheral areas, highlighting a longitudinal expansion along the roads leading to the southern exit of the city. This development reflects a pattern of expansion driven by transportation infrastructures that facilitated access to peripheral areas. During these years, the urban area increased from 3,74 km^2 in 1963 to 4,16 km^2 in 1966, indicating sustained yet moderate growth.

By 1988, the Military Geographical Institute (IGM) produced a map defining the limits of Ambato's urban growth (Figure 1). At that time, the urban area had already reached 13,98 km^2, showing a significant increase compared to previous decades. The expansion had consolidated the urban structure on the northern terrace of the Ambato River, and the surrounding growth was oriented south-eastward, also occupying the higher plain. This expansion into higher and more peripheral areas reveals clear urban growth that not only affected immediate areas but also zones further away from the city's core.

Finally, in a map prepared by the municipality, a polygon was defined that outlined the urban area of the city for 1986, covering an area of 10,94 km^2. By 2001, this polygon was updated, showing a larger area of 20,11 km^2, reflecting the continued expansion of the

Agrological classes	Agricultural quality classes
I y II	Very good
III	Buena
IV	Regular
V, VI	Bad
VII, VIII	Very bad

Table 2: Subclassification of agricultural land according to its quality. Henríquez Ruiz, (2014)

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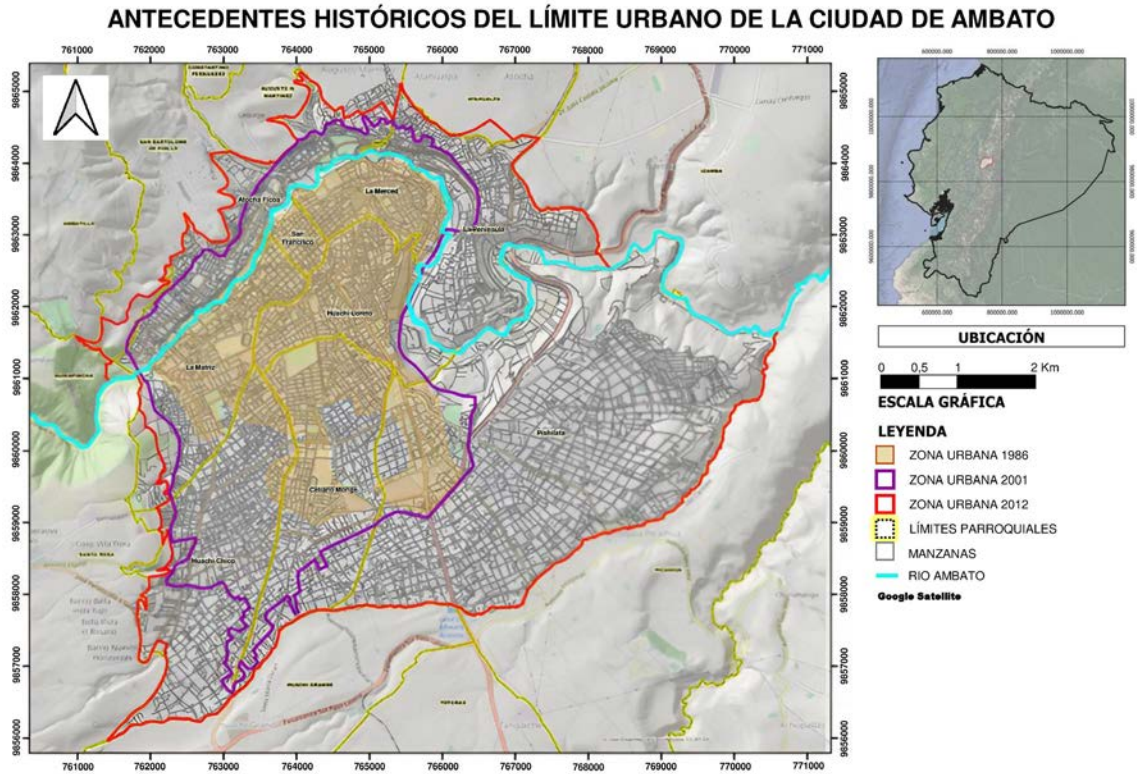

Figure 1: Historical background of the urban limit of the city of Ambato. GADM Ambato (2021)

city. By 2012, due to population growth, a new polygon was established through a municipal ordinance, defining the urban centre's extension to 46,53 km². This significant increase highlights the rapid urban development and demographic pressures faced by the city over time.

With this compilation of historical information, it becomes evident that, considering only the formal urban boundaries determined by municipal authorities since 1986, the urbanized area has doubled in a first period of 15 years and quadrupled over a 26-year period.

However, as previously mentioned, one of the issues affecting the canton is the gradual and unregulated urban growth that expands into the territory without adhering to the legally established urban boundaries. Consequently, the actual area occupied by the city tends to be larger, making it necessary to analyse this phenomenon from a more global perspective.

3.2. Historical evolution of anthropized areas

Human settlements in the canton have historically concentrated along the banks of the Ambato River, expanding mainly southward and eastward from the colonial core. According to records from the Ministry of Environment, Water, and Ecological Transition (2016), in 1990, anthropized areas covered approximately 13,42 km², significantly larger than the official urban boundary recorded in 1986.

By the year 2000, anthropized zones had expanded to 17,77 km², continuing growth primarily toward the south. In 2008, these anthropized surfaces not only extended further south but also began crossing to the northern bank of the river, reaching an area of 23,01 km². By 2018, the urban sprawl had doubled and dispersed widely across the territory, reaching a surface area of 55,18 km², thereby doubling the 2008 surface area and quadrupling that of 1990 (Figure 2).

This analysis shows that both urban boundaries and anthropized zones follow similar growth patterns, yet the official boundaries fail to reflect the reality of land occupation. The areas occupied by human activity are larger and continue expanding due to municipal inaction.

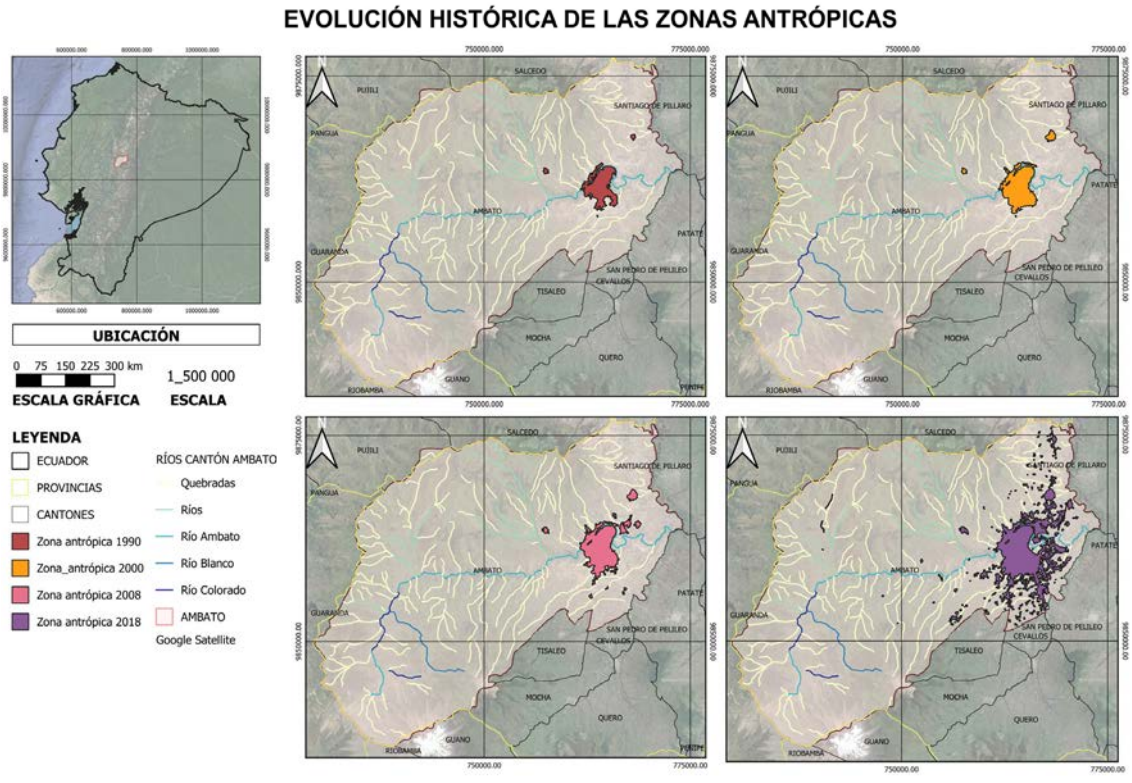

Figure 2: Historical evolution of anthropogenic zones. Ministry of Environment Water and Ecological Transition (2016)

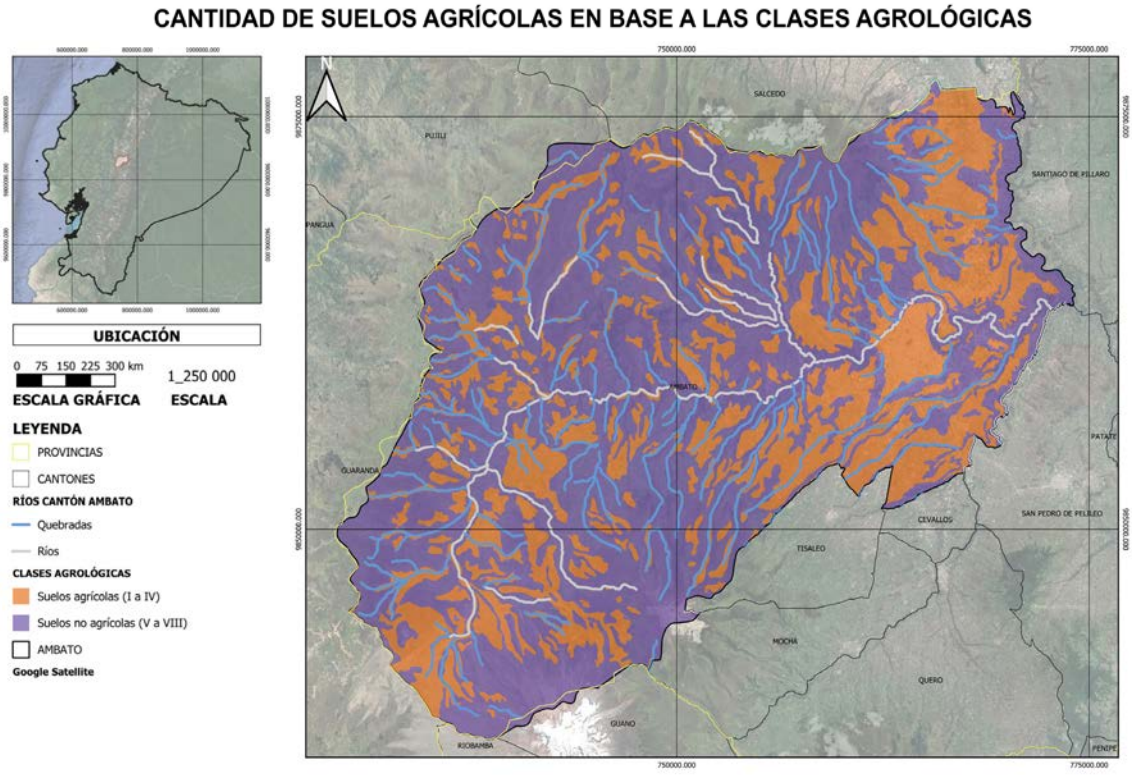

Figure 3: Number of agricultural soils based on agrological classes. Ministry of Agriculture and Livestock (2021)

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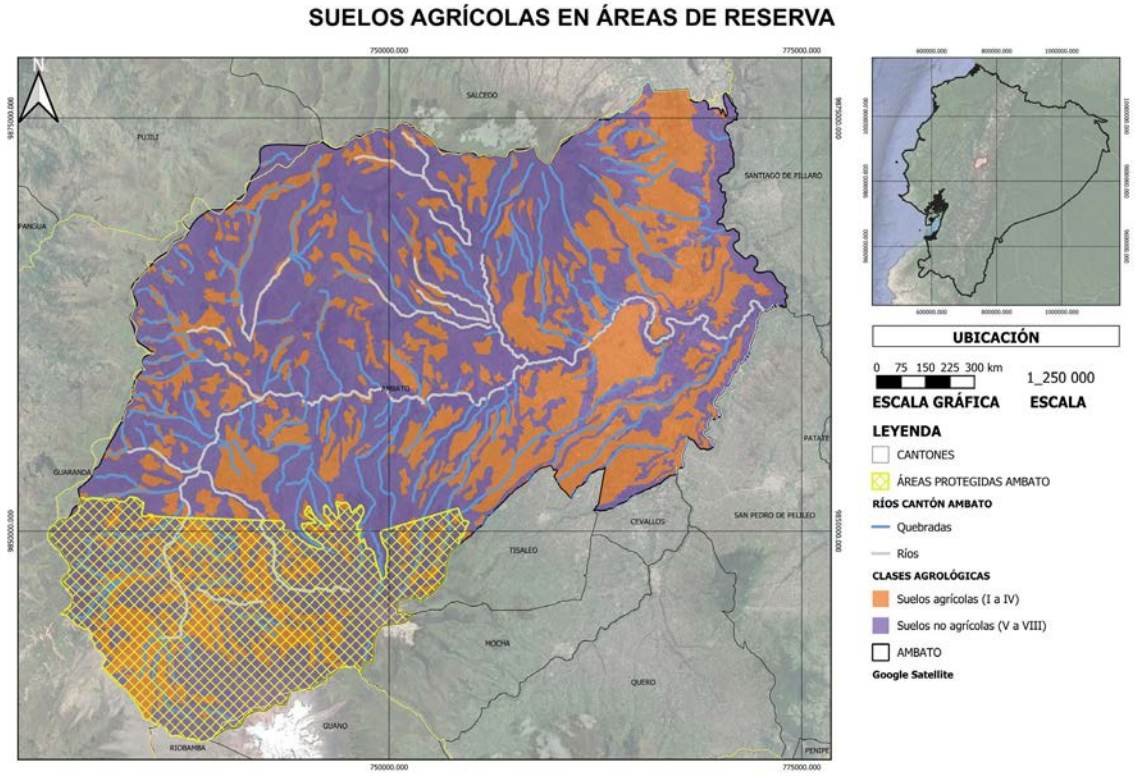

Figure 4: Agricultural soils in reserve areas. Ministry of Agriculture and Livestock (2021); Ministry of Environment Water and Ecological Transition (2016)

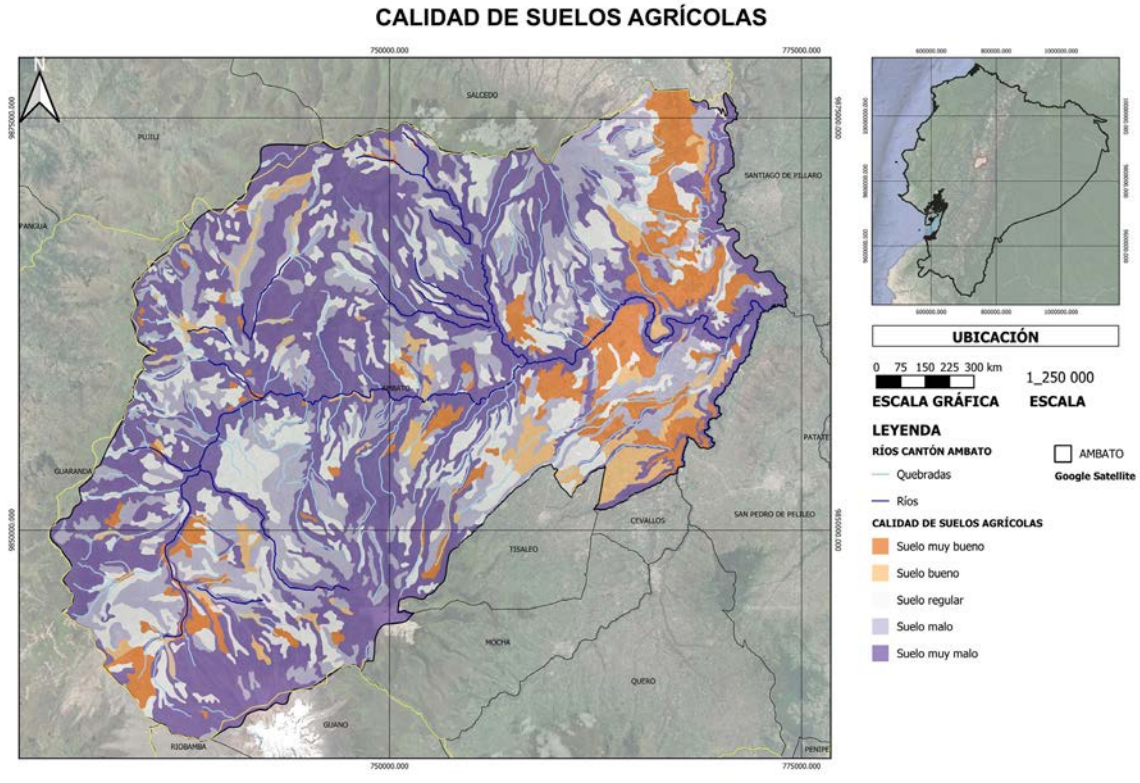

Figure 5: Agricultural soil quality. Ministry of Agriculture and Livestock (2021)

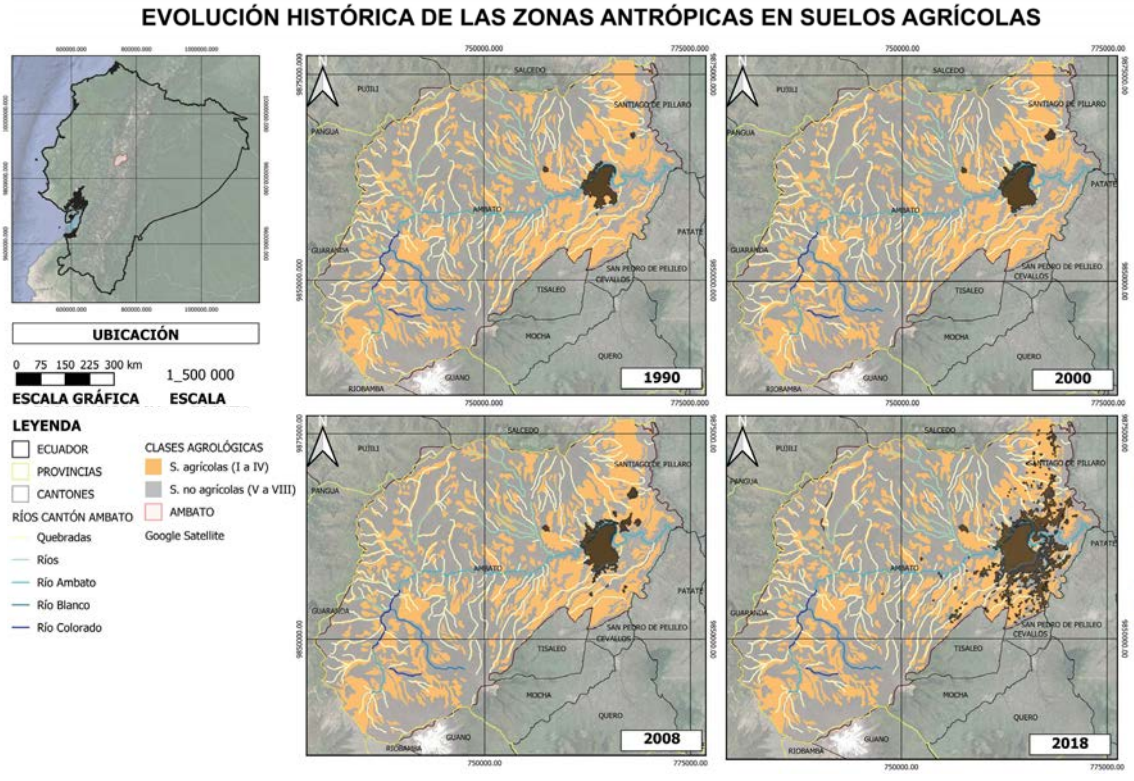

Figure 6: Historical evolution of anthropogenic zones on agricultural land. Ministry of Agriculture and Livestock (2021); Ministry of Environment Water and Ecological Transition (2016)

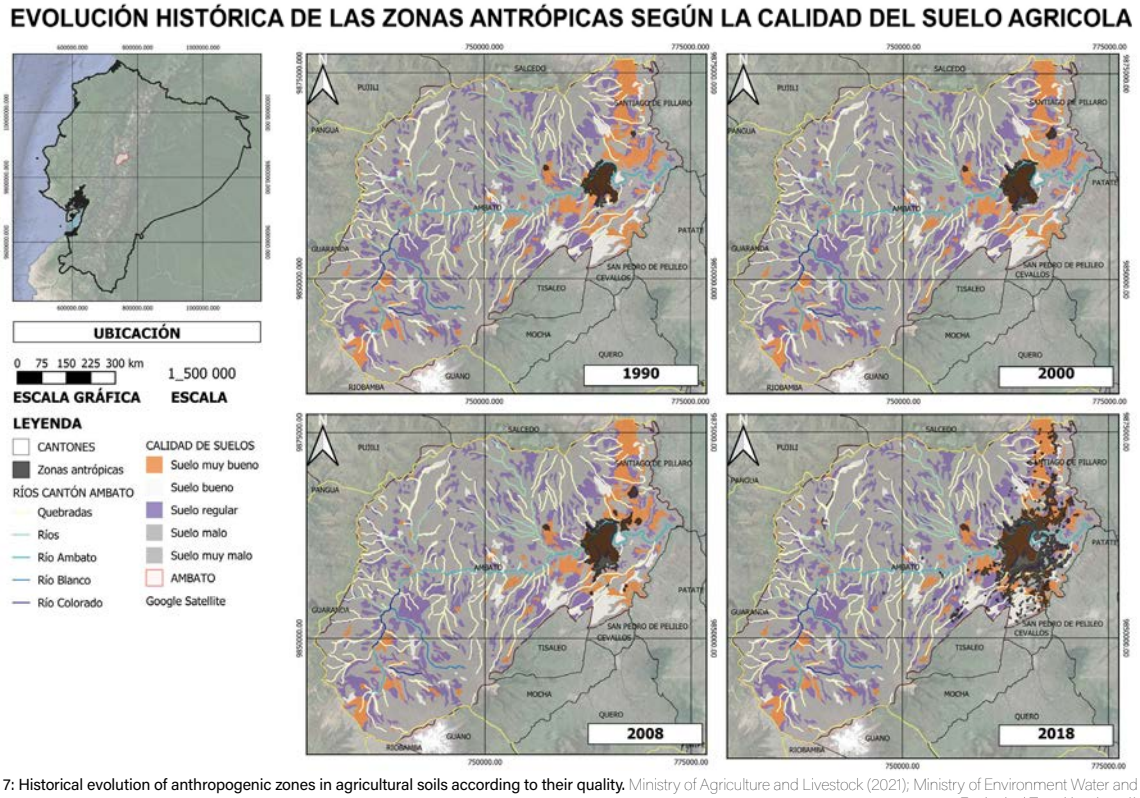

Figure 7: Historical evolution of anthropogenic zones in agricultural soils according to their quality. Ministry of Agriculture and Livestock (2021); Ministry of Environment Water and Ecological Transition (2016))

When quantifying Class I to IV agricultural soils, it is found that they represent 33,83% of the total canton area. These soils are predominantly located in the eastern zone of the canton, crossing from north to south in large, compact patches. These areas are mainly disrupted by the presence of rivers that carve through the territory, forming ravines (Figure 3).

There is also a notable presence of agricultural soils in the far western part of the canton, near Guaranda. However, these soils are limited by the Chimborazo Wildlife Reserve, which occupies the southwestern base of the canton (Figure 4).

Regarding non-agricultural soils, they account for 66,17% of the available land and are mainly located from the centre to the west of the canton, with smaller patches in the eastern sector. These soils are directly linked to the presence of rivers and gorges, which alter the topographic conditions and soil moisture, making the surrounding areas less suitable for agriculture due to high limitations.

3.4. Quality of agricultural soils

After quantifying the agricultural soils, they are further subdivided based on their quality. It was found that of the 33,83% of total agricultural soils available, only 28% are classified as very good quality. These soils are located in a linear strip that runs north to south in the eastern part of Ambato, near the cantons of Pelileo and Pillaro.

Good quality soils account for 14,23% of the agricultural soils and are primarily located around the very good soils in small patches, as well as alongside regular quality soils in larger patches.

Finally, the regular soils, that is, agricultural soils with certain limitations, account for 57,78% and are scattered throughout the cantonal territory, forming large patches near non-agricultural soils and smaller patches around very good and good agricultural soils (Figure 5).

4. Discussion and conclusions

Once the necessary baseline information for the study was gathered, the anthropogenic zones layer for the four years of analysis was overlaid on the layer of available agricultural land (Figure 6). It was observed that the anthropogenic zones began to consolidate from a central-eastern nucleus of the canton, located on the banks of the Ambato River, encroaching on agricultural territories that have gradually fallen under the mantle of urbanization.

From 1990 to 2008, while the city continued to grow, there was a compact urban area primarily on the southern bank of the river, expanding in the same direction with small extensions on the northern bank, occupying 3,93% of agricultural land in 1990, 5,07% in 2000, and 6,20% in 2008.

However, in the final 10-year period of the study, from 2008 to 2018, anthropic activities became notably more dispersed. The previously compact urban area fragmented into a series of patches expanding radially towards the north, south, and east of the historical nucleus, occupying 10,79% of the available agricultural land. This represents a five-percentage-point increase in the last decade compared to the approximately one-percentage-point growth observed in the previous decades. This shift indicates the accelerated urbanization process impacting the canton of Ambato.

Secondly (Figure 7), overlaying the anthropic zones layer from the four years of analysis with the soil quality map reveals that anthropic areas increased from occupying 0,35% of regular soils in 1990 to 3,61% in 2018. Although these values are relatively low, the areas used have multiplied by ten times.

For good-quality soils, the increase is from 0,20% in 1990 to 9,62% in 2018. This represents a significant rise, especially from 2008 to 2018, when the occupied area of good-quality soils by anthropic activities increased from 2,56% to 9,62%.

However, the most concerning finding of this research is related to very good-quality soils. Anthropogenic areas not only continue to encroach upon agricultural lands in the canton but also preferentially target the highest quality soils. Since the resettlement along the Ambato River, agricultural lands have been occupied, but when looking at the quality of soil being lost since 1990, it is evident that in that year, anthropic activities occupied 9,65% of very good soils. This increased to 11,91% in 2000, 14,07% in 2008, and reached 26,20% in 2018. This indicates that urbanization has already consumed a quarter of the best soils in the canton.

The territorial transformations observed in the canton of Ambato confirm a significant process of urbanization impacting agricultural land. The anthropic areas are located precisely in the sectors with the highest presence of cultivable land. Consequently, from the post-earthquake relocation of the city until 2008, 5,12% of agricultural land was lost. From 2008 to 2018, 10,79% of agricultural land was lost, with an average annual loss rate of 0,1% from 1990 to 2008 during a period of slow urbanization. In contrast, in the last decade of the study, this loss rate increased to an average of 0,57% per year.

Regarding soil quality, the impact is even greater. By 2018, 26,20% of very good-quality soils were lost, with an average annual loss rate of 0,27% from 1990 to 2008 during a period of slow urbanization. This loss rate accelerated to an average of 1,16% per year from 2008 to 2018.

Based on the findings obtained during this research, it is concluded that: the urban growth of the city of Ambato has permeated agricultural land, resulting in an irreversible loss in both the quantity and quality of cultivable soils available in the canton. This is because anthropogenic activity has mainly expanded into the canton's good and very good soils, paving over

approximately 25% of productive areas, which have been buried under asphalt and concrete.

The urban boundaries established in various local plans and ordinances have not had a real effect on the territory, as they have not managed to prevent the horizontal expansion of the city. This also suggests a possible lack of control by the responsible canton authorities.

Ambato, like other capitals and intermediate cities in Latin America, has shifted its historical role due to globalizing processes and urban pressures. This should serve as a warning for the authorities, as, being an intermediate city still in the process of growth and expansion, necessary measures must be taken to prevent anthropogenic areas from destroying the highest quality soils.

Finally, this study has demonstrated that if the patterns of dispersed growth over very good soils continue, the canton of Ambato would jeopardize its sustainability and agricultural role. It could no longer produce its own food and would have to depend on other cantons for food supply, similar to what is already happening in large cities.

5. Recommendations

Based on the analysis and conclusions drawn, it is essential to recommend to the Decentralized Autonomous Municipal and Metropolitan Governments that, in the exercise of their exclusive competence related to "Exercising control over land use and occupation in the canton," as determined in Article 55, Literal b of the Organic Code of Territorial Organization, Autonomy, and Decentralization (2010), they should implement sustainable planning to protect fertile soils from excessive anthropized in order to ensure food sovereignty.

It is also important to remember that the primary role of rural land is agricultural production. Therefore, it is crucial to limit excessive subdivision to preserve these areas and prevent their subsequent urbanization. Without food and water sources, human existence itself is at risk of ruin.

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